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International Growth Spillovers, Geography and Infrastructure

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Abstract

There is significant academic evidence that growth in one country tends to have a positive impact on growth in neighboring countries. This paper contributes to this literature by assessing whether growth spillovers tend to vary significantly across world regions and by investigating the contribution of transport and communication infrastructure in promoting neighborhood effects. The study is global, but the main interest is on Sub-Saharan Africa. The authors define neighborhoods both in geographic terms and by membership in the same regional trade association.

The analysis finds significant evidence for heterogeneity in growth spillovers, which are strong between OECD countries and essentially absent in Sub-Saharan Africa. The analysis further finds strong interaction between infrastructure and being a landlocked country. This suggests that growth spillovers from regional "success stories" in Sub-Saharan Africa and other lagging world regions will depend on first strengthening the channels through which such spillovers can spread—most importantly infrastructure endowments.

This paper—a product of the Environment and Energy Team, Development Research Group—is part of a larger effort in the department to understand the role of geography in economic development. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at mr10013@cam.ac.uk and udeichmann@worldbank.org.

International Growth Spillovers, Geography and Infrastructure*

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1. Introduction

Significant economic growth experiences for countries rarely occur in isolation. More typically, countries do well if their neighbors do well. The best known example is the industrial revolution. Originating in England, it quickly (by the standards of the 18th and early 19th century) spread to continental Europe in an almost contagion-like process. More recently, the "East Asian miracle" saw Japan's dynamic growth pull many of its neighbors along to middle or even high income status. Conversely, in world regions where no initial growth poles emerge and where mechanisms for transmission of spillover benefits are absent, entire regions may remain stagnant for long periods.

In this paper we aim to contribute to the analysis of spillovers between countries in different regions of the world, with a particular emphasis on growth in Sub-Saharan Africa (SSA). We take as a starting point studies by Easterly and Levine (1998) and Collier and O'Connell (2007) and extend them in two main ways. First, we look at spillovers across contiguous countries in a spatial econometric framework, but our main focus is on interaction processes that spread through regional trade agreements. Secondly, we assess a mechanism for the transmission of benefits, namely through infrastructure investments which facilitate interaction between countries through trade and communication of ideas. We are particularly interested to see if spillovers spread in a spatially homogenous process, as Easterly and Levine (1998) assume; or whether these effects are likely to be spatially heterogeneous on account of differences in the degree of spatial or institutional integration, which is closer to the assumptions in Collier and O'Connell (2007).

Understanding the scale and geographic scope of spillovers is an important piece in the overall growth puzzle. For example, one reason why cross-country growth spillovers might be localized is because spillovers of knowledge between countries are also localized. This may be the case if knowledge is embodied in intermediate goods and trade in such goods is more probable between countries which are geographically proximate[1] or which share a history of strong trading relations (Coe and Helpman, 1995, pp 861-863). Growth theory suggests that these trading partners will form so-called convergence clubs with economic growth correlated across neighboring countries (see, *inter alia*, Grossman and Helpman, 1991, Ertur and Koch, 2005, 2007). This might help to explain why successive waves of economic development have tended to be confined within relatively well-defined geographic regions.

With localized cross-country growth spillovers, not only will growth miracles tend to be spatially correlated, but so too will growth disasters. This might form part of the explanation for SSA's growth failure, both in absolute terms and relative to other developing parts of the world, in recent decades. It might also account for the large and statistically significant Africa dummy that has been a recurring finding in the empirical growth literature (Easterly and Levine, 1998). In that case, a coordinated effort between SSA nations to stimulate domestic economic growth will have a multiplier effect stemming from the neighborhood interactions implied by the existence of localized spillovers (*ibid.*, pp 136-137).

[1] Empirical evidence from the estimation of gravity models of trade provides strong support for the hypothesis that the strength of trade between two countries is inversely related to distance (see, for example, Brakman *et al*., 2009, chapter 1).

The above assumes that cross-country spillovers are equally strong between countries in different geographic regions or at different levels of development. To the extent that such spillovers are localized because they are mediated by trade, this seems unlikely. Whereas advanced industrialized countries and the emerging economies of East Asia have high levels of intra-regional trade[2], trade between SSA countries is negligible: about one-half of observed bilateral manufacturing trade flows between SSA countries are equal to zero (Bosker and Garretsen, 2008, p 12). Formal barriers to trade in the form of tariffs and quotas are a major reason, as are inefficient customs procedures and the inadequate state of transportation infrastructure within the region (Buys *et al*., forthcoming). This implies that before they can even begin to contemplate the potential leveraging of spillover effects, policymakers in the region need to cultivate such effects through policies designed to encourage regional integration. This will be particularly important for resource poor landlocked countries within the region whose only credible development strategy is integration with coastal and resource rich countries.[3] The hope is that some of the countries with a more fortunate geographic location or with better endowments will eventually take-off, dragging the resource poor landlocked neighbors along with them (Collier and O'Connell, 2007). Switzerland provides an example. Despite being landlocked, it suffers no disadvantage because it is tightly integrated with

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[2] Intra-regional trade in East Asia today approximates that within the European Union (EU) (World Bank, 2008, p 195).

[3] SSA is distinguished from the rest of the developing world by the disproportionate percentage of its population which lives in resource poor landlocked countries. According to Collier and O'Connell (2007, p 7), 35 % of the region's population lives in such countries compared to a mere 1 % in developing countries outside of SSA. These figures are based on a comparison of 43 SSA countries with a sample of 56 other developing countries and relate to the period 1990-2000.

the rest of Europe, importantly through highly developed levels of transportation and telecommunications infrastructure.[4]

This paper addresses the above issues using empirical growth regressions incorporating cross-country spillover effects. Due to data limitations we employ two samples of countries. The first, "long sample" consists of 131 countries for the period 1970-2000. This is used to test for the global importance of localized spillovers of growth between countries using panel data techniques which allow for control for both observable and unobservable time-invariant determinants of growth. We explore three different neighborhood definitions. Two of these define neighbors in purely geographic terms; with the third, on which most of our attention focuses, defining neighbors as sharing a formal regional trade agreement (RTA). By splitting the sample into sub-samples defined according to geographic regions and income levels, the paper also investigates the spatial heterogeneity of localized growth spillover effects.

The second sample consists of 142 countries and covers the period 1992-2000. This "short sample" is used to analyze the interrelationships between landlockedness, a country's level of transport and telecommunications infrastructure development, and the strength of localized growth spillovers. Given the shorter sample-period, we need to rely on cross-sectional, rather than panel, techniques.

[4] Also, in the absence of well-developed transportation infrastructure, the coastal neighbors of landlocked countries in SSA are barriers to access to world markets. By contrast, Switzerland's coastal neighbors themselves constitute the market (Collier and O'Connell, 2007, p 4).

We find some indication that growth spillovers are indeed heterogeneous and are more pronounced for neighborhood specifications based on RTA membership than on simple contiguity. Spillovers are most pronounced in OECD countries but appear basically absent in SSA. In particular, landlocked countries experienced little benefit from their coastal neighbors, and this can be attributed in large part to poor transportation and communications infrastructure. We illustrate the implications of these findings in a hypothetical simulation exercise designed to illustrate the potential welfare losses associated with the lack of integration. If Switzerland, during the period 1970 to 2000, had been exposed to the growth spillovers experienced by the equally landlocked Central African Republic, it would have forgone more than $330 billion (2000 international dollars) of GDP, all else being equal.

The layout of the remainder of the paper is as follows. Section 2 reviews related empirical literature estimating the strength of cross-country growth spillovers. Following this, section 3 sets out the different methods of defining a country's neighbors used in this paper, while section 4 presents the results of exploratory spatial analysis of our 1970-2000 panel data. This provides evidence on the extent of clustering of growth rates across countries and is, therefore, suggestive of the possible presence of heterogeneous spillover effects. Section 5 then presents results on the strength of localized cross-country spillovers using both the full sample of countries for the period 1970-2000 and various geographically and income based sub-samples. This is followed, in section 6, by the presentation of results relating to the interactions between landlockedness, infrastructure development and the strength of growth spillovers derived using the 1992-2000 sample. Section 7 presents our hypothetical simulation exercise. Finally, section 8 concludes.

2. Literature on Cross-Country Growth Spillovers

A large literature models growth between sub-national regions as being interdependent due to various factors, including growth spillovers (see, *inter alia*,; Armstrong, 1995a, 1995b; Bernat, 1996; Fingleton and McCombie, 1998; Rey and Montuori, 1998; Roberts, 2004; Angeriz *et al*., 2008, 2009; Bosker, 2007). This literature typically estimates the strength of spillovers as being given by the estimated partial correlation between the growth of one such region and a weighted average of the growth rates of neighboring regions conditional on controlling for various observed local determinants of growth.[5] To deal with the simultaneity problem which this implies, such estimation is ordinarily carried out within a single equation framework in a purely cross-sectional setting relying on maximum likelihood (ML) estimation techniques pioneered by Anselin (1988).[6, 7]

In contrast, the literature on international growth spillovers between countries which employs similar techniques is comparatively thin. Ades and Chua (1997) do not estimate the strength of growth spillovers *per se*, but rather the impact of neighboring countries' political instability. They find that such instability has a significant negative impact on domestic growth and reduces the steady-state level of income per capita in the

[5] This generates a specification referred to as the spatial lag model. Another frequently estimated type of spatial model is the so-called spatial error model. In this model, the disturbance term has a spatial autoregressive structure (Anselin, 1988).

[6] Although, applications which use spatial panel techniques are becoming more common (see, *inter alia*, Angeriz *et al*, 2008, 2009; and Arbia and Piras, 2005).

[7] As an alternative to ML, instrumental variable (IV) based estimation techniques are sometimes used (see, for example, Roberts, 2004, for an application).

domestic economy (*ibid.*, p. 287). This effect works, at least partly, through the disruption which regional political instability causes to trade. Moreno and Trehan (1997) directly examine growth spillovers, making a distinction between gross spillover effects and net spillover effects. Gross (net) spillover effects are associated with the estimated coefficient on neighboring country growth in a cross-sectional growth regression when all other explanatory variables are excluded (included) (*ibid.*, p. 405). Using data for 1965-1989, they find evidence that both types of spillover are extremely strong.

Other studies which use cross-sectional growth regressions include Abreu *et al* (2004), and Ertur and Koch (2005, 2007). Abreu *et al* (2004) find strong and statistically significant spillovers of total factor productivity (TFP) growth over the period 1960-2000. Ertur and Koch (2007) build technological interdependence directly into a modified version of the Solow model, allowing them to derive a conditional convergence style estimating equation for growth which includes spatial effects. When estimating this equation, they find neighboring growth to have a significant positive impact on domestic growth. Ertur and Koch (2005) obtain similar results, although, in this case, the authors derive their estimating equation from a two-sector model of growth. In both papers, Ertur and Koch further estimate their conditional convergence equations by applying Bayesian methods which allow for parameter heterogeneity, which they find to be important.

Easterly and Levine (1998) adopt a similar approach to the above studies. However, rather than using purely cross-sectional data, they use average growth rates for three pooled 10-year periods.[8] In doing so, they place specific emphasis on SSA in both motivating their analysis and interpreting their results. They note that including neighbor growth in their regressions eliminates the significance of the dummy variable for the region which has traditionally been found to be important in empirical growth regressions (*ibid.*, 1998, p. 133). They furthermore find large neighborhood multiplier effects, contending that these effects might have locked SSA into a slow growth pattern because they imply that slow growth in neighboring countries becomes mutually reinforcing. However, as they note, such effects also have a potentially positive upside for SSA. They imply that, if pursued in unison, a large policy change will not only have directly beneficial effects on the growth of each country in the region, but also reinforcing indirect effects. They calculate a neighborhood multiplier of 2.2, which is the factor by which the direct effects on domestic growth of a policy change are amplified if that policy change is pursued in unison (*ibid.*, pp 136-137).

All of the above studies are concerned with long-run growth spillovers. There also exist several studies which instead focus on short-run growth spillovers, using annual growth data within a panel framework. Weinhold (2002) models a country's growth as being dependent on both contemporaneous and lagged values of a neighboring growth variable. She interprets the former as capturing spatial dependence that might arise through common shocks and the latter as capturing genuine growth spillovers. In doing so, she allows for parameter heterogeneity between industrialized and developing countries, finding that significant growth spillovers exist only for the latter.

[8] Contrary to our analysis in section 5, however, they do not take advantage of the panel structure of their data set to control for time-invariant unobservable determinants of growth that might be correlated with their neighboring growth variable.

Meanwhile, Behar (2008) tests whether neighborhood spillover effects exist over and above similar effects which operate at both the regional and global levels. Depending on the exact definition of neighborhood adopted, he finds that a 1 % increase in the growth rate for all countries in the neighborhood increases the domestic rate of growth by between 0.068 % and 0.106 %. He also presents suggestive evidence that net neighborhood spillover effects are stronger in North America and Asia than in SSA, whilst, for Europe, there is no significant net neighborhood spillover effect. SSA is also found to be subject to strong regional spillover effects and Behar concludes that this result is largely driven by the commodity exporting countries, particularly the oil exporting countries (*ibid.*, 2008, p. 19). Unlike other studies which use ML or IV techniques, Behar does not explicitly control for the endogeneity of neighboring growth. He argues that, given that endogeneity only exists under the spillover hypothesis, tests based on the null hypothesis of no spillovers will still be valid. He furthermore argues that the feedback effects to own country growth implied by the existence of spillovers, and, hence, the extent of bias, are likely to be minimal (*ibid.*, p. 7).

Finally, Collier and O'Connell (2007) is the contribution which, along with Easterly and Levine (1998), is of most direct relevance to the current study. Whereas Easterly and Levine impose a spatially homogenous spillover parameter across countries in their sample and conclude that the resulting evidence of strong cross-country spillover effects might help to explain SSA's poor growth performance over recent decades, Collier and O'Connell offer a competing hypothesis. Namely, that cross-country spillover effects are likely to be much weaker between SSA countries than between countries globally on account of the region's lack of integration. This is particularly so for resource poor landlocked countries, whose performance, globally, can be expected to be more dependent than coastal and resource rich countries on neighbor growth. Consistent with this, Collier and O'Connell find that, globally, a 1 percentage point increase in neighbor growth is associated with a, statistically significant, 0.392 % increase in the domestic growth rate, rising to a 0.71% increase for resource poor landlocked countries. However, for resource poor landlocked countries in SSA, there is no significant estimated influence of neighbor growth. This implies that, *contra* Easterly and Levine, strong neighborhood multiplier effects, which have the potential to enhance the growth returns from coordinated policy actions, exist only outside of SSA.[9, 10]

In this paper we investigate in greater depth the validity of the hypotheses forwarded by Collier and O'Connell. To do so, however, we follow the majority of the literature in making use of longer-run growth data as opposed to annual data. The framework, therefore, bears more resemblance to the standard empirical growth literature, with the crucial difference that it allows for spatial effects. Through analyzing the interrelationships between landlockedness, the level of transport and telecommunications infrastructure, and the strength of cross-country growth spillovers, this paper explores in

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[9] Collier and O'Connell (2007) include a full set of year dummies in their regressions. It is not clear, however, whether or not they also include country FEs. Also unclear is precisely how they define a country's neighbors. In using annual macroeconomic data, spurious correlation associated with non-stationary data may also pose a problem.

[10] The results discussed in the main text are Collier and O'Connell's results based on OLS. They also report qualitatively similar results using IV and least absolute deviation (LAD) estimation methods (see Collier and O'Connell, 2007, p. 40, Table 20, and Table A3, p 55).

greater detail the possible reasons for heterogeneous growth spillover effects across landlocked countries in different parts of the world.[11]

3. Defining a Country's Neighbors

In previous studies, purely geographical criteria have frequently been used to identify a country's neighbors (Abreu *et al*, 2004; Ads and Chua, 1997; Behar, 2008; Ertur and Koch, 2005, 2007; Moreno and Trehan, 1997; and Weinhold, 2002). Additionally, some studies have used trade data to estimate the strength of neighbor interactions (Easterly and Levine, 1998; Moreno and Trehan, 1997; and Weinhold, 2002). We use three alternative definitions of neighborhood by specifying three alternative neighborhood, or spatial, weights (**W**) matrices:[12]

- **$\mathbf{W}_1$: Contiguity definition**

  For $\forall\, w_{ij} \neq w_{ii},\ w_{ij} = 1$ if countries i and j share a contiguity relationship; otherwise $w_{ij} = 0$.[13]

- **$\mathbf{W}_2$: Distance definition**

[11] We have confined ourselves in this section to a discussion of literature which focuses more or less directly on the relationship between the growth of an economy and the growth of its neighbors and which uses parametric techniques. However, there also exist studies which have found evidence of strong cross-country growth spillovers using non-parametric techniques (see, for example, Conley and Ligon, 2002) and which have identified spillovers from foreign R&D levels to domestic productivity (Coe and Helpman, 1995).

[12] In all analysis we follow the standard convention of row-standardizing all **W** matrices, so that $\sum_{j=1}^{N} w_{ij} = 1$.

[13] We assume that $w_{ii} = 0$ to prevent a country's growth rate being included in the definition of the growth of neighboring countries and to avoid using a country's growth rate to predict itself in the analysis of sections 5 and 6.

For $\forall\, w_{ij} \neq w_{ii},\ w_{ij} = d_{ij}^{-2}$, where d_{ij} denotes the weighted average of the bilateral distances between cities of population greater than 100,000 in countries i and j; otherwise $w_{ij} = 0$. This implies every country is a neighbor of every other country, but the strength of interaction diminishes with d_{ij}^{2}.

- **$\mathbf{W_3}$: RTA definition**

  For $\forall\, w_{ij} \neq w_{ii},\ w_{ij} = 1$ if countries i and j shared membership of a regional trade agreement (RTA) in October 2003; otherwise $w_{ij} = 0$.[14]

In constructing $\mathbf{W_1}$, we adopt a liberal definition of contiguity such that $w_{ij} = 1$ if countries i and j are separated by a land or river border or by less than 400 miles of open water, uninterrupted by the territory of a third country.[15] This allows us to maximize sample size by reducing the number of countries which would otherwise have no neighbors under more stringent definitions.[16]

Although $\mathbf{W_1}$ and $\mathbf{W_2}$ are clearly exogenous to the growth process, which is important for the regression analysis of later sections, one might worry that the same is not true for $\mathbf{W_3}$. In particular, for RTAs which came into force over the sample period, the concern exists that the probability of two countries having entered into such an agreement may have been related to their growth performances over the same period. However, we consider this concern to be relatively minor. Even where a RTA came into force only at some

[14] A full list of RTAs included in the definition of $\mathbf{W_3}$ is provided in table A1 of the data appendix.
[15] 400 miles is the maximum distance at which two 200 mile exclusive economic zones can interact (Stinnett *et al*, 2002).
[16] Our main results are robust to the use of more stringent definitions.

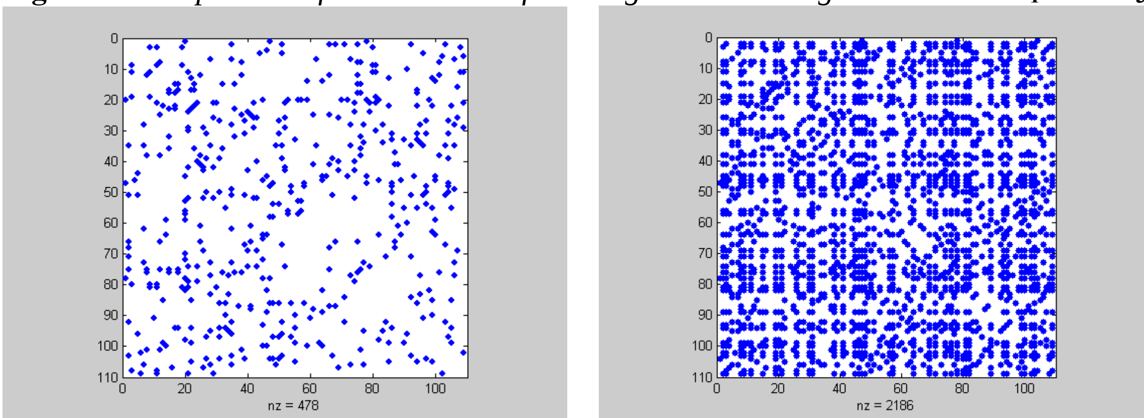
point during the sample-period, rather than before it, such an agreement usually embodies long-standing trading relationships which predate both the formal RTA and the beginning of the sample-period. In many cases, also, a new RTA builds on a previous RTA that was in force at the beginning of the period.[17] Furthermore, to assess the robustness of some of our main results to this concern, we engaged in some experimentation which involved redefining $\mathbf{W_3}$ to be based only on, respectively, pre-1991 and pre-1981 RTA membership. Although this had the effect of reducing sample size, we found our main results still to hold.[18]

Our three **W** matrices embody very different neighborhood structures. For example, using a common sample of 110 countries, figure 1 shows that $\mathbf{W_1}$ is relatively sparse compared to $\mathbf{W_3}$. While each country has, on average, just over four neighbors with $\mathbf{W_1}$, the average number of neighbors with $\mathbf{W_3}$ is just over twenty, because many countries belong to multiple, overlapping, RTAs. Furthermore, whereas 69.9 % of contiguous country pairs, as defined by $\mathbf{W_1}$, share membership of a RTA, only 15.3 % of RTA country pairs has a contiguity relationship.

[17] To demonstrate, we can cite two examples. Firstly, in our underlying data source, membership of the East African Community (EAC) is listed as dating back to 2000. This is consistent with the revival of the EAC in 2000. However, the EAC was first founded in 1967 (before collapsing in 1977), which is prior to the beginning of our 1970-2000 sample-period. Second, whilst membership of the Economic Cooperation Organization (ECO) dates back to 1985, this agreement is the successor to the Regional Cooperation for Development agreement, which was in force between 1962-1979.

[18] A related endogeneity concern is the existence of countries which withdrew from a RTA during the sample-period or of RTAs which collapsed. An example of the former is Lesotho's withdrawal from the Common Market for Eastern and Southern Africa (COMESA) in 1997. We cannot rule-out the possibility of the dissolution of RTAs and of decisions to withdraw from RTAs having been endogenous to the growth process over the sample-period. Again, however, in many cases where RTAs have been dissolved over the sample-period, they have been succeeded by other agreements (captured by $\mathbf{W_3}$) involving similar configurations of countries. For example, the UK, Denmark, Sweden, Austria and Portugal all departed from the European Free Trade Association (EFTA) during the sample-period to become members of the European Community.

Figure 1: *Comparison of the structure of the neighborhood weights matrices* $\mathbf{W}_1$ *and* $\mathbf{W}_3$



(a) Structure of $\mathbf{W}_1$ *weights matrix* *(b) Structure of* $\mathbf{W}_3$ *weights matrix*

In the remainder of this paper, our main focus is on the results obtained using $\mathbf{W}_3$, only highlighting results using $\mathbf{W}_1$ and $\mathbf{W}_2$ where these show important differences.[19] This is because our main interest is in identifying spillovers due to institutional linkages between countries that are facilitated through shared infrastructure and $\mathbf{W}_3$ relates more closely to this notion of a country's integration into its neighborhood. In specifying $\mathbf{W}_3$, no distinction is made between the degrees of integration embodied in different RTAs. Rather, in the exploratory analysis of section 4, we expect stronger clustering of growth rates where RTAs have contributed to more effective integration. Likewise, it is anticipated that the regression analysis of sections 5 and 6 will detect stronger cross-country spillover effects where integration has been more effective. Treating all RTAs equally also mitigates endogeneity concerns.[20]

[19] The full set of results using all three matrices is available upon request from the authors.

[20] For the analysis in section 5 we also considered a variant of $\mathbf{W}_3$ which restricted attention to a subset of RTAs which are more prominent. Again, although this had the effect of reducing sample size, it left the main results unchanged.

4. Exploratory Analysis of the Clustering of Cross-Country Growth Rates

Before assessing the strength of spillovers in a regression framework, we apply exploratory spatial data analysis (ESDA) techniques which assess the extent to which growth rates across neighboring countries are spatially autocorrelated. We use the average annual logarithmic growth rate of real GDP per capita as our measure of economic growth. We make use of the same sample-period of 1970-2000 on which the regression analysis of section 5 focuses, splitting this into 5-yearly cross-sections.

To provide a general indication of whether or not there is evidence of significant clustering of growth rates for each 5-year period, we use Moran's I statistic (Moran, 1948), which is defined as:

$$I = \left(\frac{\sum_i \sum_j w_{ij} (g_i - M)(g_j - M)}{\sum_i (g_i - M)^2} \right) \qquad [1]$$

where g_i and g_j denote the growth rates of countries i and j respectively, w_{ij} the corresponding weight in the neighborhood weights matrix, and M the mean rate of growth in the sample. Table 1 shows that, for $\mathbf{W_3}$ (RTA definition of neighborhoods), Moran's I is positive for all sub-periods, with the exception of 1995-2000. This indicates the presence of positive global spatial autocorrelation.[21] Furthermore, using a permutation based approach to inference[22], this spatial autocorrelation is significant at the

[21] A possible explanation for the negative Moran's I statistic for 1995-2000 might rest with the impacts of the 1997 Asian financial crisis.

[22] For a discussion of different methods of inference see Anselin (1992, p 133-135). In implementing the permutation approach, we used 999 permutations.

1 % level for all sub-periods between 1975 and 1995. This provides evidence of clustering of similar growth rates across countries in the same RTA, consistent with the general presence of localized growth spillover effects.

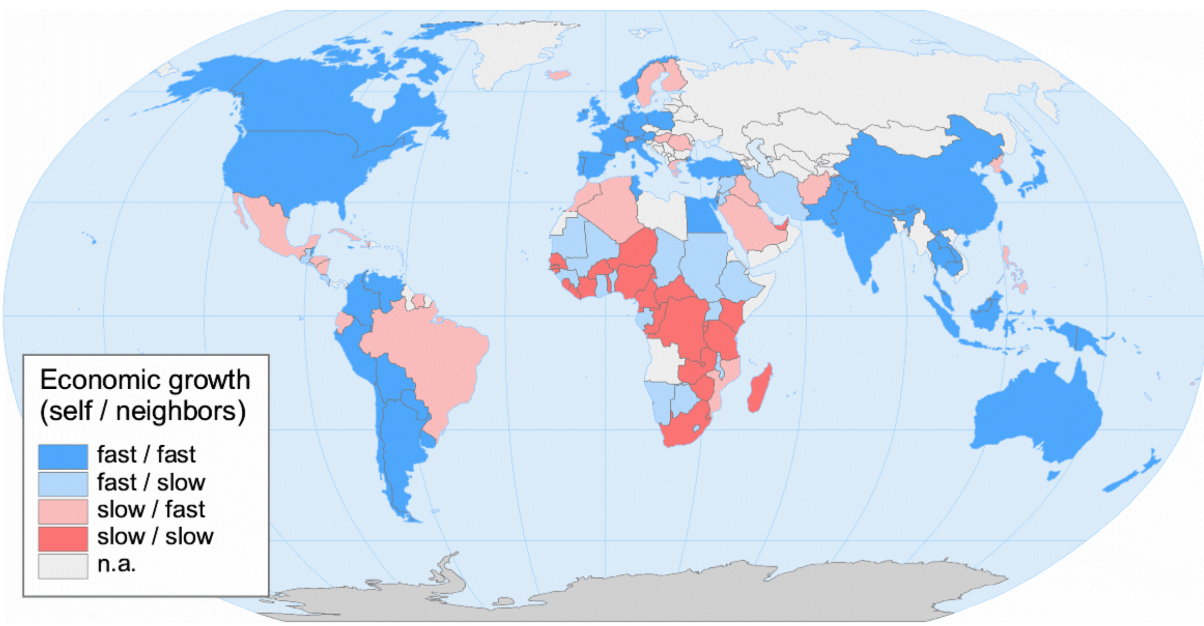
[table 1 about here]

Although Moran's I provides an indication of the general presence of clustering, it yields no insight into the possible existence of spatial heterogeneity in this process across major world regions. To explore the presence of geographically defined subgroups, we first construct a scatter plot of $\mathbf{W}_3 y$ against y where y is an $n \times 1$ vector of observations on country growth rates expressed in deviations from the sample mean. Such a scatter plot divides countries into four categories. These categories correspond to fast growing countries with fast-growing neighbors (HH); slow growing countries with slow-growing neighbors (LL); fast-growing countries with slow-growing neighbors (HL); and slow-growing countries with fast-growing neighbors (LH). Mapping these categories then provides a visual impression of the possible spatial heterogeneity in growth clustering.[23] Figure 2, which relates to 1990-1995, is typical of the results obtained. It shows several clusters of countries which shared fast growth relative to the sample mean. Notably, these clusters seem to be associated with regions of the world with higher levels of formal and informal integration (in particular, the USA-Canada, Europe, South Asia, and East Asia and Pacific). By contrast, SSA has more of a patchwork appearance with notable incidences of fast growing countries sharing RTAs with slow-growing countries. This

[23] Such a map is referred to as a Moran scatter plot map (Anselin, 1996).

indicates a greater propensity of growth rates across neighboring SSA countries to be independent of each other than in other major parts of the world or across the group of advanced industrialized countries as a whole. *Prima facie*, this supports the hypothesis that SSA is characterized by a relative absence of growth spillovers on account of the region's lack of integration, both as a result of an absence of effective formal agreements and of inadequate levels of development of transportation and telecommunications infrastructure.[24]

Figure 2: *Moran scatterplot map*
(Economic growth: average annual logarithmic growth rate of real GDP per capita growth rate, 1990-1995; neighborhood definition: belonging to the same RTA)



[24] Figure 2 provides no indication as to the statistical significance of the various clusters. It does not allow us, therefore, to distinguish between whether, for example, the spatial clustering of fast growth rates observed in East Asia and the Pacific (EAP) reflects genuine spillover effects or could have occurred simply as a result of some random spatial process. Local Moran statistics do, however, allow us to comment on statistical significance. For 1990-1995, use of these allows us to reject the hypothesis of a random spatial distribution of growth rates not only for the EAP region, but also for the USA-Canada, parts of South America and parts of SSA (for a discussion of local Moran statistics and associated approaches to inference see Anselin, 1995). Full results are available upon request from the authors.

Results using $\mathbf{W_1}$ (contiguity definition of neighborhood) and $\mathbf{W_2}$ (distance definition) are, in general, very similar to those reported above. The main difference is for the period 1970-1975 for $\mathbf{W_1}$, for which Moran's I is statistically significant at conventional levels. Therefore, on a contiguity definition of neighborhood, there is no evidence of clustering for half of the sub-periods.

5. Cross-Country Growth Spillovers and their Spatial Heterogeneity

5.1. Model specification

While the above results are suggestive, we cannot be certain whether the observed patterns of clustering are attributable to genuine spillover effects—or their absence in the case of SSA—or the existence of cross-country variations in policies, institutions and physical geography, or even the existence of shared transitional dynamics. For instance, even in a world of complete autarky, the Solow (1956) model predicts that neighboring countries with similar policies and institutions will exhibit similar growth rates if they start-off with similar initial levels of income per capita. In this section, we test whether any cross-country correlation of growth rates remains after controlling for observable determinants of growth, as well as for unobservable time-invariant determinants, using data for 1970-2000.[25] This allows us to examine whether there is evidence of spatial heterogeneity in the strength of cross-country spillover effects which might be related to varying levels of integration.

[25] The estimator we use is Elhorst's (2003) maximum likelihood (ML) estimator for a panel data model with FEs and a spatially lagged dependent variable.

Expressed in matrix and stacked (in cross-sections by time period) form, the basic estimating equation, which we apply to both our global sample and our various sub-samples, is:

$$g = (\nu_T \otimes \alpha) + \mathbf{X}\beta + \rho(\mathbf{I_T} \otimes \mathbf{W})g + \varepsilon \qquad [2]$$

$$\text{with } E[\varepsilon] = 0 \text{ and } E[\varepsilon\varepsilon'] = \sigma^2_\varepsilon \mathbf{I_{NT}}$$

where g is a $NT \times 1$ vector of country growth rates; α is a $N \times 1$ vector of country-specific time-invariant FEs; $\mathbf{X}$ is a $NT \times k$ matrix of observations on k exogenous control variables; and $\mathbf{I_T}$ and $\mathbf{I_{NT}}$ are identity matrices of dimensions $T \times T$ and $N \times T$ respectively. β is a $k \times 1$ vector of parameter coefficients and ε is a $NT \times 1$ vector of disturbance terms. The primary parameter of interest, however, is ρ. This is because the multiplication of the matrix $(\mathbf{I_T} \otimes \mathbf{W})$ with the vector g yields a $NT \times 1$ vector of weighted average growth rates, where the growth rates being averaged are those of a country's neighbors. As such, ρ is a scalar parameter which captures the strength of localized cross-country growth spillovers.

By controlling for country specific, time-invariant, determinants of growth which might otherwise be correlated with our observable independent variables, the above specification follows what, since Islam (1995), has been standard practice in much of the empirical growth literature. In this sense, our estimation approach represents an improvement over many of the previous related studies, discussed in section 2, which rely on purely cross-sectional spatial models.

In estimating equation [2], we specify a relatively parsimonious set of control variables which appear regularly in the standard empirical growth literature. Specifically, the control variables we include are, firstly, the standard controls suggested by the Solow model (Mankiw *et al*, 1992): namely, *Aver(I/Y)* (the share of investment in real GDP), *Pop. growth* (the mean logarithmic growth rate of population) and $log(GDP\ per\ capita)_{initial}$ (the log initial level of real GDP per capita). We also include *Aver(G/Y)* (the share of government expenditure in real GDP), *Openness* (exports plus imports as a proportion of real GDP) and *Civil war* (the number of years in each 5-year period characterized by civil war). By restricting ourselves to a relatively parsimonious set of controls, we are able to maximize *N* and, in particular, to sample as many neighbors of each country as possible in the specification of $\mathbf{W_1}$ and $\mathbf{W_3}$, which is desirable from the viewpoint of correctly inferring the magnitude of cross-country spillover effects. Overall, our exact cross-sectional sample size varies according to the **W** matrix used. However, for $\mathbf{W_3}$, on which we mostly focus, $N = 131$. This is considerably more than any of the studies employing long-run growth data surveyed in section 2, for which *N* is invariably less than 100.[26]

It is worth noting that, in including control variables and country FEs in our regressions, we are assuming that any spatial autocorrelation in the policy and institutions which they capture are not themselves, in part, a manifestation of growth spillover effects. As a

[26] We also experimented with the inclusion of a measure of human capital. This, however, dramatically reduced *N*, making estimation for our various sub-samples unreliable. For SSA, we also experimented with additional controls relating to resource richness and the number of years in each 5-year period a country had been free of the various policy syndromes discussed in Collier and O'Connell (2007). Inclusion of these co-variates did not materially affect any of the results presented below. Finally, we experimented with a sample period of 1960-2000. Again, because it dramatically reduced sample sizes, this made estimation for our various sub-samples unreliable and, hence, we do not report the results.

consequence, the estimates of spillover effects which we report are probably on the conservative side.[27]

5.2. Results

For $\mathbf{W_3}$, table 2 starts by presenting results using three different estimators—a pooled OLS estimator which excludes all country FEs; a standard within-group (WG) estimator which eliminates country FEs through first differencing, but which fails to control for the endogeneity of the neighbor growth variable ($\mathbf{W}y$); and our preferred ML estimator which allows for both country FEs and explicitly takes account of the endogeneity of $\mathbf{W}y$. Using pooled OLS leads to an estimated cross-country growth spillover coefficient, $\hat{\rho}$, which is both large in absolute terms and highly significant. In particular, $\hat{\rho} = 0.4569$ indicates that an increase of 1 % in the weighted average growth rate of neighboring countries generates a 0.46 % increase in the domestic growth rate. This is similar to estimates from previous studies based on either the application of purely cross-sectional spatial estimators or the application of IV estimation to pooled data. For example, Easterly and Levine (1998) obtain an equivalent estimate of ρ of 0.55 based on a smaller sample of countries using pooled data for 1960-1990. Including FEs and using the WG estimator more than halves $\hat{\rho}$ to 0.2083 without completely eliminating its statistical significance, while also controlling for the endogeneity of $\mathbf{W}y$ using an appropriate estimator, removes all evidence of a significant cross-country growth spillover effects in global data.

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[27] In particular, the estimates we report correspond, in the terminology of Moreno and Trehan (1997), to estimates of the strength of *net* growth spillover effects.

[table 2 about here]

Having found no evidence of significant spillover effects using global data, we now turn to the question of the possible heterogeneity of such effects across various geographically and income-defined sub-samples. In doing so, the main distinction that we draw is between the OECD countries, which are fully globally integrated with each other, countries belonging to SSA, between which levels of integration are low, and the countries in the rest of the world (RoW). Results for these three sub-samples are presented in table 3. For completeness, we also report results for various other geographically and income-defined sub-samples which together comprise the RoW sub-sample, although these are invariably insignificant on account of the small sample sizes.[28] For SSA, $\hat{\rho} \approx 0$ and we cannot reject the hypothesis of an absence of cross-country spillovers. Meanwhile, for the RoW, $\hat{\rho}$ is somewhat larger, but still insignificant at conventional levels. For the OECD, however, there is evidence of significant cross-country growth spillovers, at least at the 10 % level.[29] In particular, $\hat{\rho}$ indicates that a 1 % increase in the weighted average of neighbor growth rates increases an OECD country's domestic growth rate by 0.20 %.

[table 3 about here]

[28] The definition of regions corresponds to that used by the World Bank (http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/0,,pagePK:180619~theSitePK:136917,00.html). These regions are EAP (East Asia & Pacific), ECA (Europe & Central Asia, excluding Western Europe), LAC (Latin America & the Caribbean), MENA (Middle East & North Africa), OHIE (Other High Income Economies, i.e. excluding the OECD countries) and SAS (South Asia).

[29] This is based on a two-tailed test in which the alternative hypothesis makes no distinction between positive and negative spillovers. In a one-tailed test in which the null is $\rho \leq 0$ and the alternative $\rho > 0$, the estimated spillover effect would be significant at the 5 % level.

The above results are consistent with Collier and O'Connell's (2007) hypothesis that spillovers of growth are likely to be absent between SSA countries on account of the region's lack of integration. By contrast, while we do not find evidence of significant spillovers using our global sample, significant spillovers do exist between OECD countries, which are highly integrated both with each other and within their own geographic regions. The lack of spillover effects in SSA comes despite the region's "spaghetti bowl" of RTAs, which are incorporated into $\mathbf{W_3}$. Our analysis suggests that, as they stand, these agreements have proved ineffective at promoting growth spillovers within the region; this likely stems not only from deficiencies in these agreements and their application, but also from a lack of regional integration emanating from inadequate levels of transport and telecommunications infrastructure development.

Given our estimates of ρ for different sub-samples, it is also possible to calculate the size of the associated neighborhood multipliers. If we consider any one of the six 5-year cross sections in our sample, then, ignoring the country FEs for notational convenience:

$$g_t = \mathbf{X_t}\beta + \rho \mathbf{W} g_t + \varepsilon_t \qquad [3]$$

where g_t is a $N \times 1$ vector of observed growth rates for period t (t = 1970-75, …, 1995-2000), $\mathbf{X_t}$ is a $N \times k$ matrix of observations on the k controls for period t, and ε_t is the corresponding $N \times 1$ vector of disturbance terms.

Providing $\rho \neq 0$ and $1/\rho$ is not an eigenvalue of **W**, it follows:

$$g_t = (\mathbf{I_N} - \rho\mathbf{W})^{-1}(\mathbf{X_t}\beta) + (\mathbf{I_N} - \rho\mathbf{W})^{-1}\varepsilon_t \qquad [4]$$

where $\mathbf{I_N}$ is a $N \times N$ identity matrix.

Equation [4] tells us that, given $\rho \neq 0$, a country's growth rate not only depends on the observed values of the control variables for the country itself, but also on those of all other countries. Likewise, not only do domestic innovations in the disturbance term matter for growth, but so too do innovations in all other countries. All of these effects are captured by the inverse $N \times N$ matrix $(\mathbf{I_N} - \rho\mathbf{W})^{-1}$. This is a matrix of neighbor multiplier effects. If we think of a set of policy changes which are pursued in tandem and succeed in directly raising the growth rate of each country by 1 % then, from this, it follows that, provided $\rho > 0$, the final increase in the growth rate of each country will be given by $1/(1 - \rho)$ % > 1 %. It follows that $\hat{M} = 1/(1-\hat{\rho})$ gives the estimated neighborhood multiplier. Table 3 reports this for both our global sample and each of our sub-samples. Whereas, for the OECD, $\hat{M} = 1.245$, which implies that coordinated policy actions to raise growth in the OECD will be amplified by 25 % through the feedback effects associated with growth spillovers, $\hat{M} \approx 1$ for SSA. Therefore, *contra* Easterly and Levine, our results suggest that SSA countries cannot obtain enhanced growth benefits from acting in unison relative to acting alone. Rather, to obtain such benefits, they first need to cultivate appropriate channels for spillover effects through pursuing policies to promote more meaningful integration.

To conclude this section, we note how $\hat{\rho}$ varies when we use the neighborhood weights matrices $\mathbf{W_1}$ and $\mathbf{W_2}$ instead of $\mathbf{W_3}$ (table 4). The results for $\mathbf{W_2}$ are very similar to those for $\mathbf{W_3}$, except that, for the OECD countries, $\hat{\rho}$ is now significant at the 5 % level. By contrast, using $\mathbf{W_1}$ (shared borders) dramatically reduces $\hat{\rho}$ for the OECD countries to 0.1170, which is statistically insignificant at conventional levels. This is not too surprising. After all, membership of the OECD is based not on a country's geographical region, but on its level of development. Based on these results we can hypothesize that the primary mechanisms driving spillovers between the OECD countries are likely to be related to trade.

[table 4 about here]

6. The Role of Infrastructure and Geographic Location

Earlier in this paper we outlined Collier and O'Connell's (2007) finding, based on short-run growth data, that, whereas globally, resource poor landlocked countries are more dependent on the growth of their neighbors, the opposite is true for such countries in SSA. This is significant because, according to Collier and O'Connell, spillovers of growth from their neighbors represent the best hope for development for SSA's landlocked countries, assuming that these neighbors eventually succeed in taking-off. In this section, we investigate the interrelationships between the strength of longer-run growth spillovers experienced by a country, whether or not the country is landlocked, and the country's level of transport and telecommunications infrastructure development.[30] This analysis is motivated by the hypothesis that a country's effective integration into both its own region and the wider world economy will depend not only on its participation in formal trade agreements, but also on its accumulated level of investment in infrastructure that facilitates trade and other interaction. Although this applies for all economies, this is likely to be especially true for landlocked countries.

Infrastructure data comes from the World Bank's *Development Data Platform* (DDP). Following Limão and Venables (2001), we use four indicators of a country's level of infrastructure development: (1) the density of roads (i.e. number of km of road per km^2 of land area); (2) the density of paved roads (km of paved road per km^2 of land area); (3) the density of railways (km of rail per km^2 of land area); and (4) the number of telephone main lines per capita.[31] We combine these four indicators into a single measure of a country's infrastructure development by first standardizing the observations on each indicator[32] and then taking the simple un-weighted mean of the non-missing observations across the four indicators for each country.[33] Negative values of the resultant index are associated with levels of infrastructure which are low by global standards, reflecting, *inter alia*, the existence of limited road and rail networks. By contrast, positive values

[30] For brevity, we simply refer to transport and telecommunications infrastructure as infrastructure in the remainder of this section.

[31] For each country, these four indicators are themselves measured by their mean values over the sample-period (we ignore missing values in the calculation of means). This raises some endogeneity concerns as a result of possible reverse causation from a country's rate of growth to its level of infrastructure. However, the results that we report in table 5 below remain essentially unchanged if we instead use start-of-period (i.e. 1992) values for the four indicators in the construction of *Infra*.

[32] For each observation i on the infrastructure indicator I, we standardize by applying the formula $S_i = (I_i - M)/s$ where S denotes the standardized value, M the sample mean across observations on that indicator, and s the corresponding sample standard deviation.

[33] This is equivalent to assuming that the four different types of infrastructure enter as perfect substitutes to a transport services production function (Limão and Venables, 2001, p 472).

reflect levels of infrastructure which are high by global standards. Because comprehensive coverage of infrastructure data in the DDP only starts in the late 1980s/early 1990s, our analysis is restricted to a cross-sectional sample which covers the period 1992-2000. Although this rules out the use of panel data techniques, it does have the advantage of allowing us to further expand our sample, for $\mathbf{W_3}$, to 143 countries. Notably, we are now able to include the majority of nations which comprise the former Soviet Union. Many of these countries are landlocked. Indeed, while SSA has the greatest number of landlocked countries of all World Bank regions, ECA has the highest proportion (World Bank, 2008, p 101).

The regressions which we estimate take a similar form to those in section 5. In particular, we regress the annual average logarithmic growth rate of real GDP per capita on our neighbor growth variable ($\mathbf{W}y$) and a set of controls, again focusing on $\mathbf{W_3}$. This set of controls includes not only those that were considered in section 5, but also dummy variables for whether or not a country is landlocked (*LL*), whether or not a country could be classified as resource rich in 1992 (RR_{92}) and whether or not a country not classified as resource rich in 1992 became resource rich during the sample-period (RR_{new}). In addition, we include our measure of infrastructure development (*Infra*) as a control, both by itself and interacted with *LL*. However, with the exception of *Infra*, our primary interest is not so much with these extra controls, as with the various interaction effects with $\mathbf{W}y$. Thus, we interact $\mathbf{W}y$ with *LL* and/or *Infra* in various specifications.

Table 5 reports our results for two samples of countries. The first is our full sample of 142 countries (specifications 1a-5a), whereas our second excludes Equatorial Guinea (specifications 1b-5b). With Equatorial Guinea included, there is no evidence of significant interaction effects involving $\mathbf{W}y$. By contrast, excluding Equatorial Guinea does yield significant interaction effects in several of our specifications. We prefer the results excluding Equatorial Guinea. This is because Equatorial Guinea is an outlier and exhibits extreme leverage on the relationship between $\mathbf{W}y$ and y (where y is the vector of growth rates). In this relationship, not only does Equatorial Guinea have a value of Cook's d statistic of 1.3291[34], but it also has by far the highest DFFITS score (-1.7422) in the sample.[35] During the sample-period, Equatorial Guinea experienced an extremely high average annual growth rate of real GDP per capita (almost 15 %), while several of the countries (namely, the Republic of Congo, Gabon and Chad) with which it shares an RTA experienced absolute declines in real GDP per capita. Equatorial Guinea's fast growth, however, was unrelated to the decline of these countries. Rather, it was a consequence of extremely large discoveries of oil reserves in 1996. Although the inclusion of RR_{new} as a control was intended to capture the *average* impact on growth of resource discoveries, in the case of Equatorial Guinea, the impact was so large as to warrant the country's exclusion from the sample.

[table 5 about here]

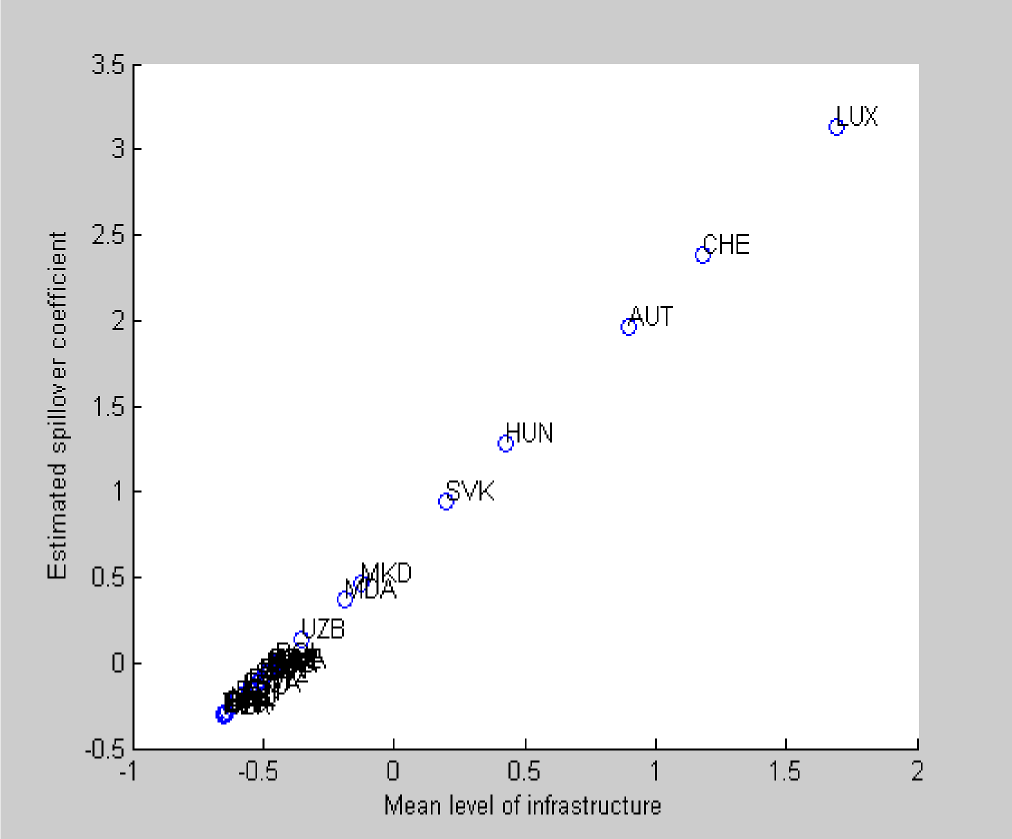
[34] Cook's d statistic measures the normalized change in the vector of fitted values, $\hat{y}$, attributable to the deletion of the corresponding observation. Values of $d > 1$ are normally considered extreme. Equatorial Guinea is the only country in the sample for which $d > 1$.

[35] The second-highest DFFITS score in the sample is -0.3831 (Uzbekistan).

Concentrating, therefore, on the results for specifications (1b-5b), we see, first of all, that *Infra* has no statistically significant direct role in determining a country's growth rate and this is true for both coastal and landlocked countries (1b). Likewise, without allowing for interaction effects, there is no evidence of significant cross-country spillovers of growth (2b). However, this changes in 3b when we interact **W***y* with *LL*. According to this specification, for coastal countries, a 1 % increase in the weighted average growth rate of their RTA neighbors generates a 0.72 % increase in the domestic growth rate, an effect which is significant at the 10 % level. By contrast, for landlocked countries, this effect is more than offset by the negative estimated coefficient on *LL*****W***y*. Indeed, for these countries, the implied estimate of the spillover coefficient, ρ, is negative.

Simply interacting *LL* with **W***y*, however, allows for no distinction between landlocked countries in SSA, and, to a lesser extent, Central Asia, which have very poorly developed transportation and telecommunications networks, and landlocked countries such as Austria and Switzerland, which are in the heart of Europe and which have excellent networks. Specification 4b, therefore, interacts **W***y* with both *LL* and *Infra*. Estimation of this specification replicates the result of a growth spillover effect for coastal countries which is significant at the 10 % level. Specifically, for such countries, a 1 % increase in **W***y* is now estimated to increase the domestic growth rate by 0.65 %. However, the positive, and significant at the 5 % level, estimated coefficient on *LL***Infra****W***y* indicates that landlocked countries whose levels of infrastructure are higher (lower) than the global average, experience a stronger (weaker) growth spillover effect than this. Indeed, from the results of 4b, we can derive an estimated spillover coefficient, $\hat{\rho}_i$, for each landlocked country in our sample. Figure 3 plots these estimated coefficients as a function of *Infra*. It shows very high $\hat{\rho}_i$ for Luxembourg (LUX), Switzerland (CHE) and Austria (AUT) on account of their sophisticated transportation and telecommunications networks. Hungary (HUN) and Slovakia (SVK), landlocked countries which have both recently joined the EU, and, in the case of Slovakia, the Eurozone, also have $\hat{\rho}_i$ in excess of that estimated for coastal countries (i.e. $\hat{\rho}_i$ > 0.65). Macedonia (MKD), Moldova (MDA) and Uzbekistan (UZB), by contrast, have $\hat{\rho}_i$ which are somewhat below that estimated for coastal countries. Finally, the $\hat{\rho}_i$ for SSA's landlocked countries, which are characterized by very poor transportation and telecommunications networks, are all clustered around zero. Interestingly, the interaction between infrastructure and spillovers is conditional on controlling for whether or not a country is landlocked. Without this distinction, *Infra* has no significant influence on the strength of spillovers (5b).

Figure 3: *Estimated country-specific spillover coefficients as a function of the level of transport and telecommunications infrastructure development, landlocked countries only*



Note: figure based on results from col. 4b of table 5

The above results show that the importance of infrastructure lies not in its direct contribution to economic growth, but in the benefits it brings to landlocked countries in their ability to experience and absorb beneficial growth spillovers from neighboring countries. It is, therefore, investment in such infrastructure that, along with more formalized trading agreements, has helped to integrate countries such as Switzerland and Austria into their neighborhoods and the global economy, and which differentiates them from the landlocked countries of, in particular, SSA. These results are consistent with Collier and O'Connell's (2007) hypothesis that, globally, landlocked countries can be expected to be more dependent on the growth of their neighbors than coastal countries, with the exception of SSA where regional integration is low.

On a note of caution, however, the results reported in table 5 are based on OLS estimation. This is problematic given the inherent endogeneity of **W**y. Ideally, we would have adopted an estimation approach which explicitly controls for such endogeneity. However, standard cross-sectional ML estimators which allow for spatial effects (Anselin, 1988), are unable to allow for interaction effects involving **W**y. Likewise, although we experimented with the use of various instruments for the variables in specifications (2a/b)-(5a/b) which involve **W**y, these experiments proved unsatisfactory. In particular, we experimented with using "spatial lags" of the control variables (i.e. **WX**, where **X** is the matrix of observations on the controls) and their interactions with *LL* and *Infra* as instruments, as well as with using the values of **W**y from 1984-1992. However, the resultant instruments proved to be very weak. In the case of the instruments based on **WX**, this was because the controls themselves have disappointing explanatory power (see, for example, the R^2 values for specifications (1b)-(5b) in table 5).

We also experimented with using an expanded set of controls, at the expense of sample size, but this did not improve matters because the expanded set did not much improve the fit of our regressions.[36] Meanwhile, in the case of the instruments based on the temporal lag of **W**y, their weakness can be explained by the fact that, globally, medium to long-term growth rates contain a strong transitory element (Easterly, 2009, p 122) which

[36] In particular, we experimented extensively with an expanded set of controls including all of the variables which Sala-i-Martin *et al*. (2004; see table 2, p. 284) report as "significantly related to growth" for the period 1960-1996. That this expanded set of controls did not help to improve the fit of our regressions and, therefore, the strength of our instruments based on **WX**, is demonstrated by the fact that the adjusted R^2 in a regression of growth on just the controls was actually lower for this expanded set of variables (0.1828) than for the equivalent specifications reported in columns 1a and 1b of table 5. This seemingly paradoxical result can be explained by the reduction in the sample size to 99 countries caused by the use of the expanded set of controls. The full set of results is available upon request from the authors.

implies that growth rates in the 1980s are poor predictors of growth rates in the 1990s, thereby also making the temporal lag of **W**y a poor predictor of **W**y. Not only did the instruments that we experimented with prove to be unsatisfactory on account of their weakness, but also because they sometimes led to theoretically implausible estimates of ρ, the co-efficient on **W**y. In particular, a spatially stable growth process requires $|\rho| < 1$. However, values of $\hat{\rho} > 1$ were obtained for some of the specifications when using IV estimation.[37]

Notwithstanding the fact the above results are based on OLS, we are reasonably confident that our main conclusions are not driven by endogeneity of **W**y. This is so for several reasons. Firstly, as Behar (2008, p 7) argues, **W**y is only endogenous under the hypothesis of growth spillovers. Therefore, tests of the rejection of the null of no spillovers based on OLS estimation retain some validity. Second, as noted above, when entered in our specifications by itself without any interaction effects, the coefficient on **W**y is not significantly different from zero (specification 2a, table 5). It is only when **W**y enters in more subtle forms that we detect significant spillover effects. Third, and finally, when we re-estimate the simple spillover specification, 2b, with no interaction effects using a ML estimator which does explicitly take into account the simultaneity of y and **W**y, we find that the estimated spillover coefficient is actually larger than that reported in

[37] Our estimates of ρ_i for Luxembourg, Switzerland, Austria and Hungary implied by specification 4b in table 5 also fall outside of this range (see figure 3). However, this does not necessarily imply a spatially unstable growth process for these countries because they have amongst their neighbors non-landlocked countries for which $|\hat{\rho}_i| < 1$. Thus, while faster growth of these countries' neighbors is amplified when spilling-over to Luxembourg, Switzerland, Austria and Hungary, the reverse feedback to the neighbors is then damped. This leads to the possibility of a spatially convergent growth process, even if it appears locally unstable in places.

table 5. Therefore, in this instance, it seems that, if anything, the use of OLS leads us to under-, rather over-, estimate the strength of growth spillover effects.[38]

7. The Costs of Fragmentation for Sub-Saharan Africa's Landlocked Countries

Having provided evidence of heterogeneous spillover effects across landlocked countries and related these to differences in the strength of integration, in this section we present the results of a simulation exercise which is designed to be suggestive of the welfare losses associated with a lack of integration for such countries. This exercise answers the hypothetical question: What would have been the cumulative loss in real GDP over the period 1970-2000 had Switzerland, a landlocked country which is fully integrated with both its immediate neighborhood and the world economy, been subject to spillovers of the strength that the Central African Republic experienced? Thus, our exercise is akin to the thought experiment of relocating Switzerland—with all its domestic human and physical capital—from the heart of Europe so that it takes the Central African Republic's place in the heart of SSA.

To implement this exercise, we draw on our results from section 5 and make a highly conservative set of assumptions. Hence, we assume that the only parameter which changes from Switzerland's viewpoint is ρ, i.e. the strength of the cross-country spillover effect. From the results of table 3, therefore, we assume that Switzerland shared the estimated value of ρ of 0.0430 with the rest of SSA rather than the value of 0.2350 estimated for it as part of the OECD sub-sample. Apart from this, however, we assume

[38] The results from the application of this ML estimator are available upon request from the authors.

that everything else for Switzerland remains unchanged. Thus, the change in neighborhood is assumed not to impact on any of Switzerland's observable or unobservable determinants of growth over the period 1970-2000.[39] Furthermore, we assume that the impacts of the observed determinants of growth for Switzerland remain as estimated for the OECD sample. Finally, we assume no change in the underlying pattern of shocks experienced by Switzerland over the period 1970-2000.

More concretely, our simulation methodology comprises of five steps. In **step 1** we calculate Switzerland's new growth rate of real GDP per capita, y^{CHE}, for the period 1970-1975 given its change in neighborhood. In particular:

$$y_{1970-75}^{CHE,SSA} = \hat{\alpha}^{CHE,OECD} + x_{1970-75}^{CHE}\hat{\beta}^{OECD} + \hat{\rho}^{SSA}\sum_{j=1}^{n_{SSA}} w_{CHEj}\, y_{1970-75}^{SSA,j} + u_{1970-75}^{CHE,OECD} \qquad [5]$$

where $\hat{\alpha}^{CHE,OECD}$ is the size of Switzerland's FE as estimated using the OECD sub-sample, $x_{1970-75}^{CHE}$ is the $1 \times k$ row vector of observations on the control variables for Switzerland for 1970-1975, $\hat{\beta}^{OECD}$ is the corresponding $k \times 1$ column vector of parameters estimated using the OECD sub-sample, $\sum w_{CHEj}\, y_{1970-75}^{SSA,j}$ is the weighted average growth rate for Switzerland's neighbors in SSA now that it has taken the place of the Central African Republic in $\mathbf{W_3}$, $\hat{\rho}^{SSA}$ is the estimated value of the spillover parameter from our original SSA sub-sample, and $u_{1970-75}^{CHE,OECD}$ is the estimated residual for Switzerland for 1970-1975 using the OECD sub-sample.

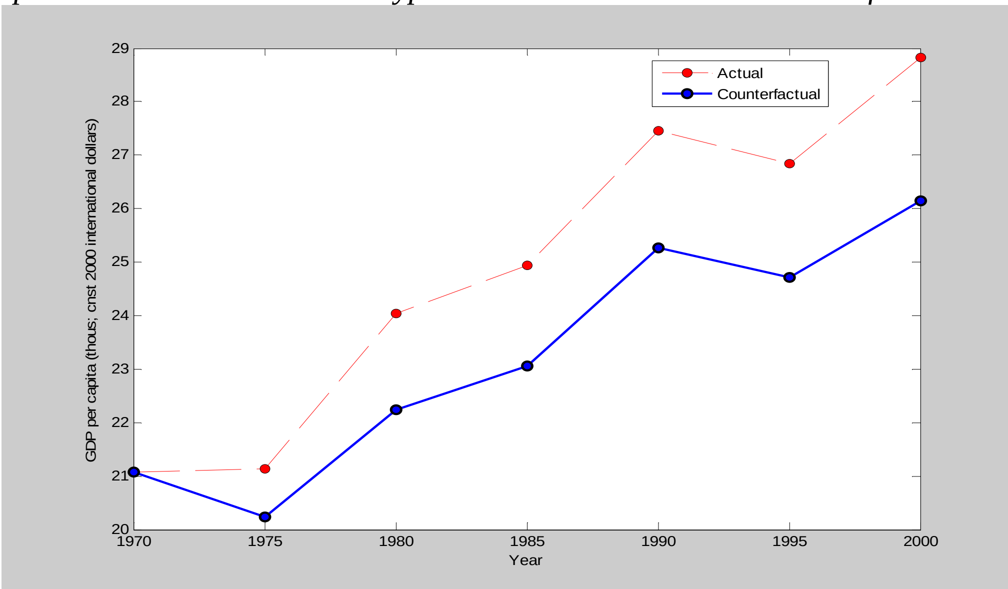
[39] With the exception of *log(GDP per capita)*$_{initial}$ (see below).

Having calculated y^{CHE} for 1970-1975, in **step 2** we update the growth rates for all of the other countries in SSA for 1970-1975. This is necessary because these countries are now, either directly or indirectly, connected to Switzerland, instead of the Central African Republic, through $\mathbf{W_3}$. **Step 3** then involves iterating steps 1 and 2 until convergence between successive iterations in each element of the vector of SSA country growth rates, including Switzerland in the place of the Central African Republic, is achieved.[40] In **step 4** we calculate *log(GDP per capita)*$_{1975}$ for both Switzerland and all other countries in SSA. This is required because the value of this control variable in one sub-period is endogenous to growth in the previous period. Finally, in **step 5**, we repeat steps 1 – 4 for all subsequent time periods (i.e. for 1975-1980, ..., 1995-2000).

Figure 4 shows the results. In 1970, Switzerland's real GDP per capita in the counterfactual simulation is the same as its actual observed level. However, as time progresses, an ever-widening shortfall of simulated GDP per capita below its observed level emerges as a result of the weaker spillover effects. By 2000, Switzerland's real GDP per capita is 9.3 % lower under the counterfactual. Cumulating the losses over 1970-2000 gives an aggregate real GDP loss of $334 billion (2000 international dollars), which was the equivalent of 162 % of Switzerland's real GDP in 2000.

[40] Convergence is assumed to have occurred when the absolute difference between each country's growth rate in successive iterations is less than 0.001 %.

Figure 4: *Simulating the impact on Switzerland's real GDP per capita of weaker growth spillovers associated with its hypothetical relocation to the centre of sub-Saharan Africa*



Although the welfare gains for the Central African Republic from greater spillovers would obviously be lower in absolute terms than Switzerland's simulated losses, it is clear that the welfare losses associated with weak cross-country spillovers stemming from a lack of integration are very large for landlocked countries. Indeed, if anything, our simple exercise considerably underestimates the losses. This is because of the highly conservative assumptions which underpin the exercise.

8. Conclusion

In this paper, we have examined the strength of cross-country spillovers of long-term growth both globally and in various geographically and income defined sub-samples. Our objective was to find evidence for the possible spatial heterogeneity of such effects which can be linked to differences in the integration of countries, both with their immediate neighborhoods and globally. We have further investigated the relationship between the strength of any growth spillover effect, landlockedness, and the level of development of a country's transport and telecommunications networks. In doing so, we were motivated by the observation that a country's ability to benefit from spillovers is likely to depend not only on its participation in formal trade agreements, but also on the level of development of such networks and this is especially true for landlocked countries. Indeed, in the case of SSA, the development of such infrastructure is likely to be a critical prerequisite for cultivating beneficial growth spillovers. This is because there already exists a "spaghetti bowl" of RTAs which, in themselves, have proved to be largely ineffective.

Overall, our panel data results provide moderate evidence in favor of the existence of heterogeneous growth spillover effects for the period 1970-2000. In particular, while such cross-country spillovers have been a significant determinant of growth for OECD countries at the 10 % level, we cannot reject the hypothesis that spillovers are absent in SSA countries. This seems consistent with the high level of integration that exists between the OECD countries and the lack of effective—as compared to *pro forma*—integration observed within SSA. Furthermore, our cross-sectional analysis for 1992-2000 suggests that, globally, coastal economies experience, on average, stronger growth spillover effects than landlocked countries. This result, however, is attributable to the fact that most landlocked countries are located in SSA and, as such, are characterized by very poorly developed transport and telecommunications networks. Once we allow the level of development of such networks to interact with our neighboring growth variable for landlocked countries, we uncover a dichotomy of experiences.

On the one hand, landlocked countries such as Luxembourg, Switzerland, Austria and Hungary, which are in the heart of Europe, experience stronger spillovers of growth from their neighbors than the average coastal country on account of their high levels of transport and telecommunications infrastructure. On the other hand, the landlocked countries of SSA, not to mention Central Asia, experience essentially no beneficial growth spillovers from their neighbors. This is because of, *inter alia*, inadequate investments in transport and telecommunications infrastructure accumulated over long periods of time. Our hypothetical simulation exercise of allowing Switzerland to take the place of the Central African Republic in SSA demonstrates that the welfare losses associated with missing out on such beneficial spillovers are substantial.

The above conclusions support and extend previous arguments and findings made by Collier and O'Connell (2007). They are less consistent with those of Easterly and Levine (1998) who have partly attributed SSA's growth failure to reinforcing spillovers of slow growth. Such arguments seem inconsistent not only with our findings, but also with the fact that some countries in the region, such as Botswana, have experienced fast growth, while growth in neighboring countries has floundered. This casts doubt on the notion that a coordinated stimulus across SSA might benefit from a multiplier effect such that the overall impact on long-term economic growth far outweighs the direct initial impact on each country's domestic growth. Rather, our results suggest that more effective integration involving, in particular, investments in transport and telecommunications are first required to generate the transmission mechanism for such a multiplier effect. This is particularly true for the region's landlocked countries.

Data appendix

This appendix details the different sources of data used to construct the various variables used in the analysis of this paper.

Non-spatial variables

Real GDP per capita*, *Pop. Growth*, *Aver(I/Y)*, *Aver(G/Y)*, *Openness

The underlying data is from the Penn World Table v 6.2 (Heston *et al.*, 2006) and was downloaded from http://pwt.econ.upenn.edu/php_site/pwt_index.php. *Pop. growth* is the (natural) logarithmic growth rate of population and was calculated as $[\ln(P_{i,t}) - \ln(P_{i,t-T})]/T$ where $P_{i,t}$ denotes country i's population level in year t and T is the number of years over which the population growth rate is calculated. *Aver(I/Y)*, *Aver(G/Y)* and *Openness* are all measured as averages over the period of interest, with the level of *Openness* in any one year being given by $(X_{i,t} + M_{i,t})/Y_{i,t}$ where $X_{i,t}$ denotes country i's level of exports in year t, $M_{i,t}$ its level of imports and $Y_{i,t}$ its level of real GDP. Real GDP is measured in 2000 constant international dollars.

Civil war

Measured as the number of years in a given time period for which a country was characterized by civil war, where civil war is itself defined as an intra-state conflict involving 1000+ annual battle deaths. The underlying data is from the *International Peace Research Institute*, Oslo, and was downloaded from http://www.prio.no/CSCW/Datasets/.

LL

A dummy variable indicating whether or not a country can be classified as landlocked (1 = landlocked, 0 = not landlocked). Both the Democratic Republic of Congo and Sudan are classified as landlocked, despite the fact that they have coasts. This is on the basis of their lack of access to their coast lines. Ethiopia is classified as being landlocked throughout the 1970-2000 sample-period. The data is from the data appendix of Collier and O'Connell (2007), supplemented with information from Wikipedia.

RR_{92}, RR_{new}

Dummy variables indicating respectively whether or not a country could be classified as resource rich in 1992 (1 = resource rich, 0 = not resource rich) and whether or not a country for which RR_{92} = 1 became resource rich during the sample-period 1992-2000 (1 = became resource rich, 0 = did not become resource rich). The variables are constructed from data contained within the data appendix of Collier and O'Connell (2007) which gives the first year in which they classify a country as being resource rich based on several criteria, supplemented, in some cases, with judgemental adjustments.

Infra

The construction of this variable is explained in section 6 and follows Limão and Venables (2001), as well as Bosker and Garretson (2008). The underlying data is from the World Bank's *Development Data Platform*.

Spatial variables

As explained in detail in section 3, three different neighborhood weights matrices (referred to in the main text as $\mathbf{W_1}$, $\mathbf{W_2}$ and $\mathbf{W_3}$) were used to construct variables measuring the weighted average growth rate of a country's neighbors. The contiguity data used to construct $\mathbf{W_1}$ is from the Correlates of War (COW) v 3.1 direct contiguity dataset and was downloaded from www.correlatesofwar.org/COW2%20Data/dDDirectContiguity/DCV3desc.htm. Meanwhile, the weights in $\mathbf{W_2}$ are based on the weighted average of the bilateral distances between cities of population greater than 100,000 in countries *i* and *j*. The population data used to identify these cities is from the Global Rural Urban Mapping Project (GRUMP) database, Center for International Earth Science Information Network (CIESIN), the Earth Institute, Columbia University. This data was downloaded from http://sedac.ciesin.columbia.edu/gpw/. Distances between cities are measured using the great circle method. Finally, the regional trade agreement (RTA) data used to construct $\mathbf{W_3}$ was kindly supplied by Souylemane Coulibaly and was originally sourced from the World Trade Organization. The RTAs included in $\mathbf{W_3}$ are listed in table A1 below.

Table A1: List of Regional Trade Agreements (RTAs) included in the definition of W3

Association of Southeast Asian Nations (ASEAN), **Arab Maghreb Union (AMU)**, Arab Free-Trade Area (ArFTA), Australia New Zealand Closer Economic Agreement (ANZCERTA), Asia-Pacific Economic Cooperation (APEC), Baltic Free-Trade Area (BAFTA), Bangkok agreement (BANGKOK), Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), **Cooperation Council for the Arab States of the Gulf (CCASG)**, **Central American Common Market (CACM)**, **Andean Community (CAN)**, **Caribbean Community and Common Market (CARICOM)**, **Central European Free-Trade Agreement (CEFTA)**, **Economic and Monetary Community of Central Africa (CEMAC)**, Commonwealth of Independent States (CIS), **Common Market for Eastern and Southern Africa (COMESA)**, East African Community (EAC), Eurasian Economic Community (EAEC), European Union (EU), **European Cooperation Organisation (ECO)**, **Economic Community of West African States (ECOWAS)**, **European Economic Area (EEA)**, European Free Trade Association (EFTA), General System of Trade Preferences among Developing Countries (GSTP), Latin American Integration Association (LAIA), **Southern Common Market (MERCOSUR)**, Melanesian Spearhead Group (MSG), **North American Free-Trade Agreement (NAFTA)**, Overseas Countries and Territories (OCT), Agreement on Trade and Commercial Relations between the Government of Australia and the Government of Papua New Guinea (PATCRA), Protocol Relating to Trade Negotiations among Developing Countries (PTN), South Asian Association for Regional Cooperation (SAARC), Southern Africa Customs Union (SACU), **Southern African Development Community (SADC)**, **SAARC Preferential Trading Agreement (SAPTA)**, **South Pacific Regional Trade and Economic Cooperation Agreement (SPARTECA)**, Tripartite Agreement (TRIPARTITE), **West African Economic and Monetary Union (WAEMU)**

The agreements listed correspond to those which have been notified to GATT/the WTO and which were in force as of 13 October 2003. RTAs which are considered to be more prominent are in bold.

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Tables

Table 1: *Moran's I test results for global spatial autocorrelation ($\mathbf{W}_3$ = row-standardized RTA matrix)*

Period	**Moran's I**	**Mean**	**Z-value (prob)**
1970-1975	0.2969	0.2641	1.3418 (0.1797)
1975-1980	0.2492***	0.1747	2.7219 (0.0065)
1980-1985	0.1261***	0.0169	3.8288 (0.0001)
1985-1990	0.2190***	0.0899	4.7558 (0.0000)
1990-1995	0.0904***	0.0068	3.1678 (0.0015)
1995-2000	0.1538	0.1877	-1.3435 (0.1791)

*** indicates significance at the 1 % level

Inference is based on a permutation approach to inference (see Anselin, 1992, p 133-135). 999 permutations were used.

Table 2: *Results from estimation of spillover model for global sample: Spatial versus non-spatial methods, 1970-2000 (*$\mathbf{W}_3$ *= row-standardized RTA matrix)*

Variable	Pooled OLS	Spatial FE	Spatial-ML
log(GDP per capita)$_{initial}$	***-0.0079*** ***(-5.6129)***	***-0.0630*** ***(-12.3311)***	***-0.0646*** ***(-13.5756)***
Pop. growth	-0.1287 (-1.2821)	0.0173 (0.1277)	0.0163 (0.1325)
Aver(I/Y)	***0.1398*** ***(7.6365)***	0.0735 (2.3576)	***0.0729*** ***(2.5538)***
Aver(G/Y)	-0.0160 (-1.08)	-0.0499 (-1.5466)	***-0.0594*** ***(-2.0589)***
Openness	***0.0130*** ***(3.9492)***	***0.0458*** ***(5.9707)***	***0.0465*** ***(6.6667)***
Civil war	***-0.0026*** ***(-2.8101)***	***-0.0044*** ***(-3.1309)***	***-0.0045*** ***(-3.5582)***
Wy	***0.4569*** ***(5.4217)***	**0.2083** **(2.3494)**	0.0700 (0.9624)
Spatial multiplier $\hat{\beta}_{naive}$	1.8414	1.2631	1.0309
R^2	0.1683	0.2637	0.4429
$\overline{R}^2$	0.1608	-	0.3252
N	131	131	131
NT	786	786	786

Spatial FE corresponds to fixed effects (within-group) estimator; spatial-ML to Elhorst's (2003) spatial fixed effects panel data estimator; in the case of Spatial FE, R^2 excludes effect of spatial fixed effects on model fit; Figures in brackets are asymptotic t-statistics; Bold indicates significance at the 10 % level; bold and italics significance at the 5 % level

Table 3: *Results from estimation of dynamic panel spillover model, 1970-2000* (**W_3** *= row-standardized RTA matrix)*

Variable	Global	OECD	SSA	RoW	*Other groupings* EAP	ECA	LAC	MENA	OHIE	SAS
log(GDP per capita)$_{initial}$	***-0.0646***	***-0.03988***	***-0.0828***	***-0.0673***	***-0.0532***	***-0.1327***	***-0.1066***	***-0.1163***	***-0.0994***	-0.0116
	(-13.5756)	***(-6.59240)***	***(-7.6604)***	***(-10.6408)***	***(-4.2122)***	***(-7.9345)***	***(-8.3078)***	***(-4.9193)***	***(-7.1910)***	(-1.1045)
Pop. growth	0.0163	-0.42442	***0.5213***	***-0.3602***	-0.5068	***-2.7633***	***-1.2089***	0.6508	0.0434	***-0.9924***
	(0.1325)	(-1.38112)	***(2.2824)***	***(-2.1760)***	(-0.4816)	***(-2.2235)***	***(-2.0104)***	(0.6697)	(0.1755)	***(-2.0890)***
Aver(I/Y)	***0.0729***	**0.057831**	**0.0842**	0.0155	0.1928	***0.2794***	***0.2422***	***-0.2958***	**-0.2350**	**0.3219**
	(2.5538)	**(1.73223)**	**(1.8270)**	(0.3044)	(1.5486)	***(3.3451)***	***(2.7986)***	***(-2.2091)***	**(-1.7595)**	**(1.6522)**
Aver(G/Y)	***-0.0594***	**-0.12698**	0.0369	***-0.1018***	0.0233	-0.0091	**-0.0702**	-0.0892	-0.1538	0.0179
	(-2.0589)	**(-1.88543)**	(0.5946)	***(-2.7449)***	(0.2348)	(-0.0663)	**(-1.7085)**	(-0.8488)	(-1.5709)	(0.1191)
Openness	***0.0465***	***0.07472***	***0.0494***	***0.0385***	0.0203	***0.0712***	***0.0469***	***0.0658***	***0.05160***	***-0.1014***
	(6.6667)	***(7.043378)***	***(3.6360)***	***(4.0360)***	(1.0083)	***(3.0688)***	***(2.6144)***	***(2.3431)***	***(2.6909)***	***(-2.3676)***
Civil war	***-0.0045***	**-**	***-0.0083***	-0.0009	-0.0010	-0.0019	-0.0037	0.0017	-	-0.0014
	(-3.5582)		***(-3.6251)***	(-0.5348)	(-0.2277)	(-0.5810)	(-1.4879)	(0.5081)		(-0.5476)
Wy	0.0700	**0.20000**	0.0170	0.0940	0.0481	-0.1619	-0.0269	0.0300	0.0711	-0.0169
	(0.9624)	**(1.79340)**	(0.1278)	(1.0355)	(0.2674)	(-1.6039)	(-0.2261)	(0.1593)	(0.7166)	(-0.0823)
Spatial multiplier	1.0309	1.24500	1.0173	1.1038	1.0505	0.8607	0.9738	1.0309	1.0765	0.9834
$\hat{\beta}_{naive}$	3.5914	2.62280	4.1595	3.6840	3.1798	5.3511	4.7815	5.0056	4.6063	0.9940
R^2	0.4429	0.6277	0.4616	0.4526	0.5528	0.8775	0.5175	0.4864	0.5582	0.7563
$\overline{R}^2$	0.3252	0.5330	0.3343	0.3304	0.3944	0.7834	0.3845	0.2686	0.4271	0.6432
log(LIK)	1594.8341	459.9361	484.2164	780.881	144.5984	75.3253	297.7167	99.5591	150.1743	100.9331
$\hat{\sigma}^2$	0.0010	0.0001	0.0013	0.0011	0.0007	0.0001	0.0005	0.0009	0.0016	0.0005
N	131	24	42	65	11	4	21	8	14	7
NT	786	144	252	390	66	24	126	48	84	42

All specifications include country-specific time invariant fixed effects and were estimated using the Elhorst (2003) spatial fixed effects panel data estimator; Figures in brackets are asymptotic t-statistics; Bold indicates significance at the 10 % level; bold and italics significance at the 5 % level

Table 4: *Comparison of the estimated spillover coefficient across different W matrices*

	W_3 (RTA)	W_2 (Distance)	W_1 (Contiguity)
Global	0.0700	0.0480	0.0510
OECD	**0.20000**	***0.2200***	0.1171
SSA	0.0170	0.0430	0.0380
RoW	0.0940	0.0330	0.0641

Bold indicates significance at the 10 % level; bold and italics significance at the 5 % level

Table 5: *OLS results from estimation of hybrid cross-sectional spillover model, 1992-2000 (*$\mathbf{W_3}$ *= row-standardized RTA matrix)*

	Full-sample (N = 142)					*Excluding Equatorial Guinea (N = 141)*				
	1a	**2a 3a**	**4a**	**5a**		**1b**	**2b**	**3b**	**4b**	**5b**
Constant	0.0720***	0.0726***	0.0718***	0.0723***	0.0734***	0.0730***	0.0726***	0.0677***	0.0683***	0.0764***
	(2.8694)	(2.9266)	(2.9200)	(2.9208)	(2.8556)	(2.8819)	(2.8253)	(2.6219)	(2.6211)	(2.9316)
LL	-0.0151***	-0.0151***	-0.0133	-0.0158**	-0.0150***	-0.0139***	-0.0135**	0.0062	-0.0209***	-0.0129**
	(-3.0607)	(-3.0959)	(-0.7171)	(-2.4016)	(-3.0979)	(-2.7616)	(-2.5965)	(0.5825)	(-3.5548)	(-2.4309)
RR_{92}	0.0034	0.0036	0.0033	0.0035	0.0036	0.0035	0.0035	0.0032	0.0039	0.0035
	(0.5173)	(0.5665)	(0.5057)	(0.5548)	(0.5681)	(0.5797)	(0.5272)	(0.4928)	(0.5892)	(0.5370)
RR_{new}	0.0751***	0.0666***	0.0667***	0.0663***	0.0673***	0.0396***	0.0413***	0.0360***	0.0335***	0.0425***
	(3.1754)	(2.8785)	(2.7296)	(2.7988)	(2.8218)	(4.6853)	(4.6289)	(4.1401)	(3.8277)	(4.6276)
$L(GDP\ pc)_{92}$	-0.0095***	-0.0088***	-0.0090***	-0.0089***	-0.0088***	-0.0094***	-0.0097***	-0.0104***	-0.0103***	-0.0098***
	(-3.3784)	(-3.0537)	(-3.0610)	(-3.0341)	(-3.0323)	(-3.2647)	(-3.3929)	(-3.5893)	(-3.5385)	(-3.4372)
Pop. growth	-0.2681	-0.2549	-0.2448	-0.2528	-0.2525	-0.2826	-0.2870	-0.2758	-0.2968	-0.2735
	(-1.1930)	(-1.1121)	(-1.0609)	(-1.0952)	(-1.1011)	(-1.2545)	(-1.2884)	(-1.2584)	(-1.3546)	(-1.2089)
Aver(I/Y)	0.1788***	0.1884***	0.1898***	0.1818***	0.1889***	0.1691***	0.1590***	0.1531***	0.1505***	0.1618***
	(5.2914)	(5.3994)	(5.3903)	(5.3923)	(5.3865)	(4.8859)	(4.3015)	(3.9972)	(3.9149)	(4.3807)
Aver(G/Y)	0.0185	0.0178	0.0187	0.0182	0.0182	0.0162	0.0140	0.0162	0.0171	0.0155
	(0.7035)	(0.6834)	(0.7348)	(0.7088)	(0.6878)	(0.6251)	(0.5390)	(0.6550)	(0.6729)	(0.5821)
Openness	0.0055	0.0043	0.0044	0.0044	0.0042	0.0049	0.0060	0.0073	0.0073	0.0052
	(0.9846)	(0.7389)	(0.7560)	(0.7436)	(0.7142)	(0.8849)	(1.0649)	(1.3139)	(1.3055)	(0.9050)
Civil war	-0.0008	-0.0008	-0.0008	-0.0008	-0.0008	-0.0007	-0.0007	-0.0009	-0.0008	-0.0008
	(-1.0129)	(-0.9453)	(-1.0283)	(-0.9704)	(-0.9551)	(-0.8652)	(-0.8999)	(-1.1241)	(-1.0226)	(-0.9428)
Infra	0.0031	0.0038	0.0036	0.0037	0.0056	0.0038	0.0033	0.0017	0.0020	0.0114
	(0.9546)	(1.1265)	(1.0461)	(1.1034)	(0.4478)	(1.1826)	(0.9961)	(0.5075)	(0.5991)	(0.9604)
LL*Infra		0.0085	0.0103	0.0051	0.0086	0.0065	0.0053	0.0138**	-0.0300	0.0059

		(1.3524)	(1.5024)	(0.1710)	(1.3536)	(1.0373)	(0.8110)	(2.2290)	(-1.6084)	(0.8959)
Wy	0.0079	-0.3358	-0.2647	-0.3182	-0.3564	-	0.2333	0.72 01*	0.6503*	0.0994
	(1.2592)	(-0.8793)	(-0.5883)	(-0.7397)	(-0.8917)		(0.8103)	(1.8318)	(1.6761)	(0.3065)
LL*Wy	-	-	-0.2453	-	-	-	-	- 1.0373**	-	-
			(-0.3874)					(-2.3285)		
LL*Infra*Wy	-	-	-	0.1367	-	-	-	-	1.4640**	-
				(0.1177)					(2.1174)	
Infra*Wy	-				-0.0675					-0.3035
					(-0.1523)					(-0.7329)
$\hat{\beta}_{naive}$ (% pa)	0.9156	0.8516	0.8405	0.8405	0.8547	0.9034	0.9382	0.9990	0.9870	0.9444
R^2	0.3758	0.3811	0.3811	0.3811	0.3811	0.2843	0.2891	0.3161	0.3102	0.2878
$\overline{R}^2$	0.3230	0.3235	0.3183	0.3183	0.3126	0.2232	0.2224	0.2461	0.2396	0.2149
$\hat{\sigma}^2$	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Moran I stat.	-0.8016	0.1601	0.4286	0.4286	0.2184	-0.0438	-0.9141	-0.5608	-0.5528	-0.8564
(p-value)	(0.4228)	(0.8728)	(0.6682)	(0.6682)	(0.8272)	(0.9651)	(0.3607)	(0.5749)	(0.5804)	(0.3918)

Figures in brackets are t-statistics based on White heteroscedasticity consistent standard errors; * indicates significance at the 10 % level, ** significance at the 5 % level, *** significance at the 1 % level